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Discussions and Replies — Session XII

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DISCUSSIONS AND REPLIES SESSION XII

Discussion on paper titled: "Dynamics of Massless Rigid Foundation Resting on Elastic Half Space", by M. Mashhour, S. Abdel-Salam, and S. El-Naggar, Paper No. 12.01

By: Hatem I. ElBastawisy, Postdoctoral Fellow, Civil Engineering Department, Univ. of South Carolina, USA

An important step in current methods of dynamic analysis of rigid massive machine foundations is the determination (using analytical or numerical methods) of the dynamic impedance functions. Results are now available for the complete dynamic impedance matrix of rigid rectangular foundations with aspect ratios L/B over the law and medium frequency range [1]. For the vertical, horizontal, and rocking modes, in particular, results are available even for moderately high values of a_o [2,3,4]. The Authors presented a numerical procedure for the evaluation of dynamic impedance functions for a rectangular foundation resting upon an homogenous, isotropic, elastic half-space. The method of analysis simplifies the mechanical behavior of the soil-footing contact surface by assuming a relaxed boundary condition approximation which based on the observation that only a weak coupling mode exists. The consistency of the proposed solution is verified by a comparison with literature. The effect of the aspect ratio, Poisson's ratio been investigated. These results can be directly used to make satisfactory and inexpensive predictions of the dynamic behavior of machine foundations without the need to resort a costly computer programs for evaluating the impedances; this should be a great value for preliminary design calculations.

Natural soil deposits very rarely have uniform properties within large depths from the loaded surface. More typical is the presence of a stiffer material or even bedrock at a relatively shallow depth. The response of a foundation on a soil stratum underlain by such a stiffer medium can be substantially different from the response of an foundation resting on a uniform half-space. It is, thus, imperative to study the dynamics of massless foundations on such soil deposits. Specifically two types of idealized soil profiles shall be considered:

1 - a homogenous soil stratum over a rigid base, and
2 - a homogenous soil stratum over a homogenous half-space.

These models represent a wide spectrum of actually encountered soil profiles in practice. In that presentation, the following groups of parameters which appreciably influence the dynamic impedance shall be identified:

1 - the embedment effect, expressed as D/B, where D is the depth from the surface to the horizontal soil-footing interface
2 - the hysteretic critical damping ratio of the soil
3 - the degree of anistropy and rate of inhomogeneity (change of shear modulus from the surface to depth equal B)

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4 - Savidis, S. A. "Analytical Methods for the Computation od Wave fields," Dyn. Meth. Rock Mech., 1977, Vol. 1, pp. 225.

Discussion on paper titled: "Development of New Stiffness and Damping Expressions for Footing Vibrations," by H.V.P. Truong and P.J. Moore, Paper No. 12.04.

By Mark R. Svinkin, Goble Rausche Likins and Associates, Inc., Cleveland, USA.

The author suggested a new expression for the forcing function in which periodic forcing function has additional constant component. Naturally, final equations for the resonant frequency and the maximum amplitude of vibration have usual acceptable forms.

Expressions of vertical and horizontal added soil masses have been simplified as compared with known ones.

Discussion on paper titled: "Response of Embedded Circular Flexible Foundations", by N. Gugunski, Paper No. 12.05.

By Mark R. Svinkin, Goble Rausche Likins and Associates, Inc., Cleveland, USA.

The author studied effects of foundation flexibility on vertical response of a circular foundation for various embedment and soil layering conditions. The stiffness matrix approach was used to derive the solution of vertical vibrations of circular flexible foundations embedded in a viscoelastic layered half-space. The "ring method" approach was employed in the analytical solution of soil-foundation interaction.

Interesting conclusions presented in the paper indicate a significantly different responses of flexible and rigid foundations, but this difference decreases considerably with embedment of flexible foundations and loading applied at the central portion of the foundation.

Certain obtained results were expected, for example the stiffer foundation, the higher the static stiffness or the fact that a larger area of a foundation is participating in the load transfer for stiffer foundations.

Two results seem strange.
1. There are significant displacement distribution variations of a rigid foundation even for low dimensionless frequency.
This is contradictory with actual vibration displacements of rigid foundations.
2. Even a small depth of embedment causes significant increase of the stiffness of a flexible foundation.
It is difficult to imagine how soil medium with

modulus smaller approximately in 100-3000 times, depending on soil type, the concrete modulus can enhance the stiffness of flexible foundations. Probably, some additional interpretation of obtained results is necessary according to acceptable approaches.

Discussion on paper titled: "Response of Embedded Circular Flexible Foundations", by N. Gucunski, Paper No. 12.05

By: Hatem I. ElBastawisy, Postdoctoral Fellow, Civil Engineering Department, Univ. of South Carolina, USA

The author described the stiffness matrix approach to the solution of vertical vibration of a circular flexible foundation embedded in a viscoelastic layered half-space. Results of a parametric study, represented by soil reaction distribution and displacement, were presented. Important parameters been addressed in this study include: the stiffness ratio, depth of embedment, soil stratification and loading distribution. The paper concluded that a significant different responses for flexible and rigid shall be expected.

The response of flexible foundations was investigated during the past ten years by different researchers[1,2,3,4,5]. The results of their studies indicated that the response of flexible foundation can differ significantly from that of rigid plates, especially for high-frequency range. The author in his work addressed some parameters which significantly affect the system response. This is very encouraging, but some other parameters which proved to be significant in case of surface foundations may also be examined in this parametric study. For example:

Poisson's Ratio affects the magnitude of the displacement. The displacement distribution is affected little for low frequency ratio for all Poisson's ratio except 0.5. The soil reaction distribution is not affected by the variation of the Possion's ratio for low frequency ratio, minor differences is observed for higher frequencies. On the other hand, the impedance functions are strongly influenced by the Possion's ratio.

The damping ratio has little effect on the displacement distribution. Negligible effect on the soil reaction. On the other hand, the damping ratio of soil significantly influences the impedance functions.

The mass and stiffness distribution affect the impedance functions. For low stiffness ratio, increasing the rigidity at the center of the plate hardly affects the impedance coefficient. On the other hand, increasing the rigidity and the mass at the edge of the plate affects the impedance coefficients significantly. For high stiffness ratio the damping part of the impedance is affected only by the mass ratio, while the stiffness part is affected by both the mass and the change of plate's rigidity.

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5 - N. Gucunski and R. Peek, "Parametric Study of Vertical Vibrations of Circular Flexible Foundationson Layered Media," Earthquake Eng. Struct. Dyn., Vol. 22, 685-694, 1993.

Discussion on paper titled: "Interaction of Adjacent Machines", by J.P. Lee and J.A. Bohinsky, Paper No. 12.14.

By Mark R. Svinkin, Goble Rausche Likins and Associates, Inc., Cleveland, USA.

The authors have analyzed vibrations of the flexible floor that supported two adjacent rotating machines. Frequency analysis performed for various mode shapes of the floor could reveal relative rigidity of the support structures, some "weak spots" and promote improvement of the structural design.

Obtained results - maximum computed velocities at bearing housings are shown in Tables 1 and 2 for the in-phase and out-phase loading conditions. It is pointed out that critical condition occurred when unbalanced forces from the two machines with frequency of 12.6 Hz were out-of-phase.

On the basis of these results, it seems that the cause of the most critical condition is vertical floor vibrations for second mode rather than the amplification of floor vibrations by the interaction between two rotating machines.

The authors present an interesting paper, but derived results would be more beneficial if comparison of computed and measured data of the floor vibrations was done.

Discussion on paper titled: "The Reliability Aspects in Dynamic Engineering", by G. Singh and B.M. Das, Paper No. 12.21.

By Mark R. Svinkin, Goble Rausche Likins and Associates, Inc., Cleveland, USA.

No doubt that reliability aspects are very important for design of foundations under machines with dynamic loads.

Probabilistic approach suggested by authors can be useful for certain cases, but what is the application range of this approach? In illustrative example, authors received contradictory results as compared with deterministic approach which yielded pretty reasonable value, two times greater than 200 cpm, of resonant frequency of natural vertical foundation vibrations. Value of this frequency calculated with probabilistic approach showed unrealistic result (Barcan, 1962; Svinkin, 1995).

Many uncertainties of machine foundation-soil systems have deterministic nature. Changes in any part of whole machine foundation-soil system can be the cause of arisen vibrations. Often heightened foundation vibrations are impossible to predict using ordinary calculation methods prior to the machine have been installed and began to work since evaluation of vibration causes is beyond the possibilities of existing routine computation procedures. However, available knowledge about the phenomena of machine foundation vibrations and corresponding experience give a chance to analyze intolerable vibrations and make diagnostic of their appearance (Svinkin, 1993).

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Paper No. 12.04
Reply by H.V.P. Truong and P.J. Moore

The authors wish to express their thanks to the discussor who took an interest in the paper by presenting his discussion.

Paper No. 12.05
Reply by Nenad Gucunski

I thank Mark Svinkin for his valuable discussion of the paper. The following is the response to his questions related to the displacement distribution and effects of the shear modulus of soil on the response of the flexible foundation:

1) All the foundations examined have a finite rigidity. As indicated in the paper foundations with stiffness ratio$\geq$10, and the loading applied on the core, exhibit displacement variations in the radial direction (Figs. 2, 7 and 8). In this case a foundation acts as a cantilever slab. A foundation with a high rigidity has ability to transfer loading to the outer portions. This results in significant soil reaction magnitudes near the edge, as can be observed in Fig. 3. In return soil reactions acting on this cantilever slab, due to a significant moment arm, cause deflections of foundations of even high stiffness ratios. This phenomena is not observed for the foundations with uniformly distributed loading, where the soil reaction close to the edge of the foundation is balanced, in the greatest part, by the loading itself. (Even though there will be a phase difference between those two at higher frequencies.)

2) Effects of the depth of the embedment and soils rigidity are illustrated in Figs. 5-11. An explanation of the effects of these two is in close relationship to the explanation above about the displacement distribution. Variation of either the thickness or the shear modulus of soil (Figs. 5, 6, 10 and 11) changes its ability to resist deformation. It will be reflected by different soil reaction distributions, and consequently by different displacement distributions. Significant effect of the foundation embedment on the increase of foundation impedances was reported by a number of authors. In this study that effect is even more pronounced due to an assumption of a foundation being covered by soil over the entire surface.

Paper No. 12.14
Reply by J. P. LEE, and J. A. BOHINSKY
Brown & Root, Inc., 10200 Bellaire Blvd., Houston, Texas 77072

The authors would like to express their sincere thanks to Mr. M. R. Svinkin of Goble Rausche Likins and Associates, Inc. for his discussion of the paper and would like to provide the following reply.

Several analyses were performed to assess the effects of two adjacent machines supported on a flexible floor. In each analysis, all significant modes, including the second mode, were included. It was found that, for the cases investigated, the maximum vibration amplitude occurred when two adjacent machines were in operation rather than only one was running.

Another comment was concerning measured results. We agree with Mr. Svinkin that It would be beneficial if measured data were available for comparison with the calculated results. However, in the field, the actual dynamic load is small compared to the given dynamic loads during normal operating condition. It requires the use of dynamic load generation devices and careful phase-angle adjustments to obtain usable results. Unfortunately, the funding was not available and the measurements were not made.